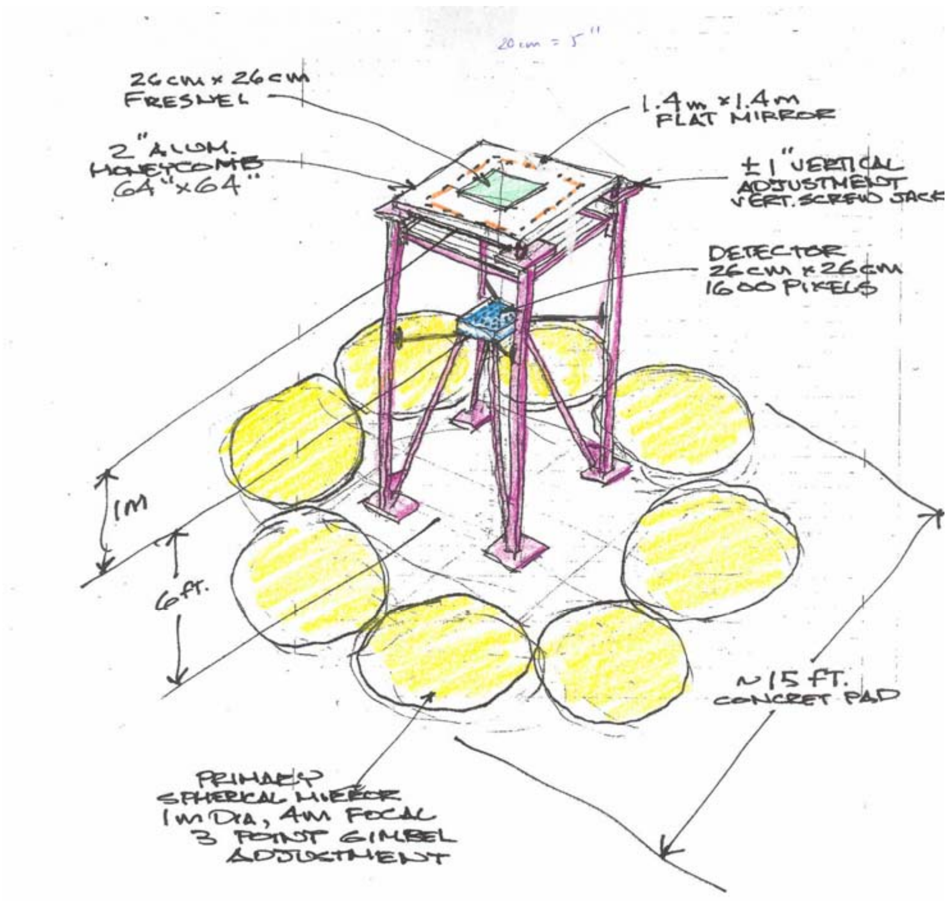
Monte Carlo Programs for TRICE Telescope



Current Programs and procedures :

CORSIKA – air shower (including Cerenkov photons) generator

Reference : D. Heck, J. Knapp, J.N. Capdevielle, G. Schatz, and T. Thouw;
Report FZKA 6019 (1998), Forschungszentrum Karlsruhe;
http://www-ik.fzk.de/~heck/corsika/physics_description/corsica_pysics.html

CorsikaRead – unpacks binary output (of Cerenkov file) of CORSIKA (SM uses read program that comes with CORSIKA package, LH uses custom routine).

FormatRead – formats unpacked CORSIKA Cerenkov output for TRICE application (SM needs this additional step to get proper format for telescope program)

TELE3 – propogates Cerenkov photons thru TRICE telescope to Camera – makes PAW ntuple for analysis

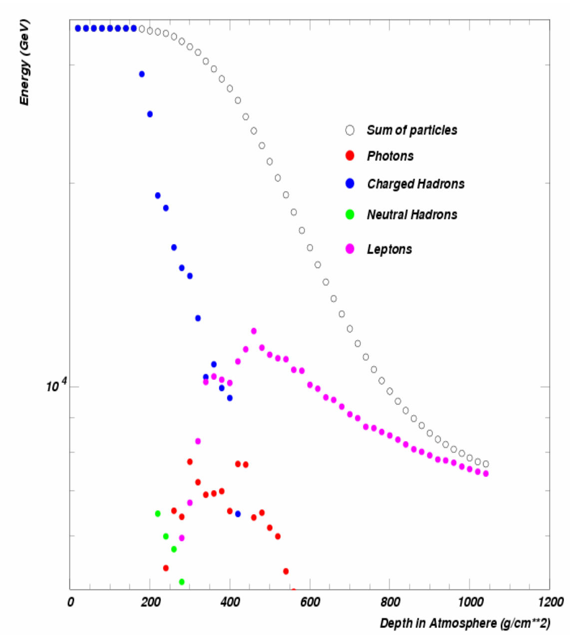
CORSIKA Air Shower Generator :

Input file for steering CORSIKA :

```
RUNNR   25                               number of run
EVTNR   1                                number of first shower event
NSHOW   1                                number of showers to generate
PRMPAR  5626                             particle type of prim. particle
ESLOPE  -2.7                             slope of primary energy spectrum
ERANGE  1.E5  1.E5                       energy range of primary particle
THETAP  0.  0.                           range of zenith angle (degree)
PHIP    0.  360.                         range of azimuth angle (degree)
SEED    1   0   0                        seed for 1. random number seq.
SEED    2   0   0                        seed for 2. random number seq.
SEED    3   0   0                        seed for 3. random number seq.
OBSLEV  200.E2                           observation level (in cm)
ELMFLG  T   T                            em. interaction flags (NKG,EGS)
RADNKG  200.E2                           outer radius for NKG lat.dens.distr.
ARRANG  0.                               rotation of array to north
CERARY  21 1 1000. 1000. 350. 350.       definition of cherenkov array grid
CERSIZ  6.                               bunch size Cherenkov photons
CERFIL  T                                Cherenkov output to extra file
CWAVLG  300.  450.                       Cherenkov wavelength band
CSCAT   1  0. 0.                         scatter Cherenkov events
TSTART  T                                T(true)starts time at entry to atm
FIXHEI  3000000.  0                      first interaction height & target
FIXCHI  0.                               starting altitude (g/cm**2)
MAGNET  18.8  52.1                       magnetic field centr. US
HADFLG  0  0  0  0  0  2                 flags hadr.interact.&fragmentation
QGSJET  T  0                             use QGSJET for high energy hadrons
QGSSIG  T                                use QGSJET hadronic cross sections
ECUTS   0.3  0.3  0.003  0.003           energy cuts for particles
MUADDI  T                                additional info for muons
MUMULT  T                                muon multiple scattering angle
LONGI   T  20.  T  T                     longit.distr., step size, fit, out
MAXPRT  100                              max. number of printed events
ECTMAP  1.E3                             cut on gamma factor for printout
STEPFC  1.0                              mult. scattering step length fact.
DEBUG   F  17  F  1000000                debug flag and log.unit for out
DIRECT  /users/zeus/srm/veritas/corsika/results/  output directory
PAROUT  T T                              table output
DATBAS  T                                write .dbase file
USER    srm                              user
EXIT                                     terminates input
```

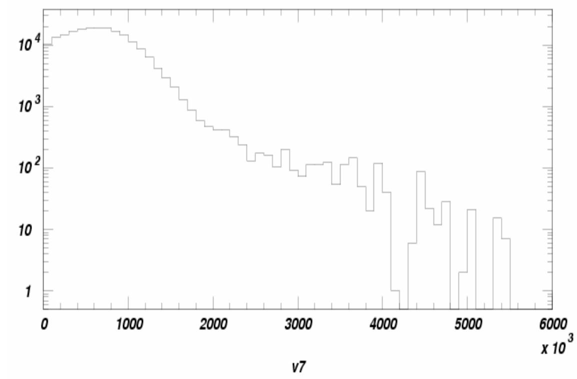
The items highlighted in red are particularly important for generation of Cerenkov photons. The magnetic field parameters are set to those for ANL's latitude and longitude and the observation level is also estimated to be the approximate height of the TRICE site above sea level (in cm). The keyword "CERFIL" set to T (true) causes CORSIKA to create a separate output file containing the Cerenkov photons. Complete information for all of the input keywords and their values can be found in the CORSIKA manual.

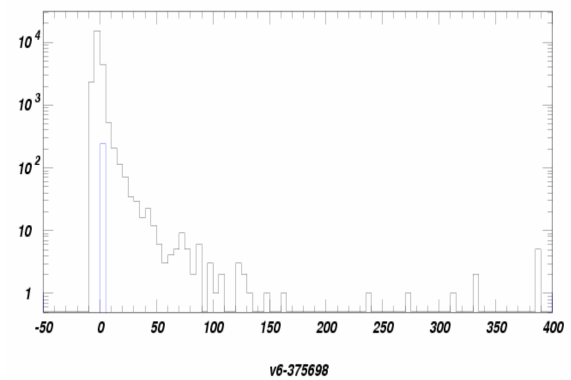
The following plot shows the particle composition of an air shower from a 32 TeV Fe nucleus incident on the atmosphere – the particle production is separated by type and shown versus depth in units of g/cm^2. The first interaction occurred at a depth of ~150 g/cm^2 as shown in the plot.



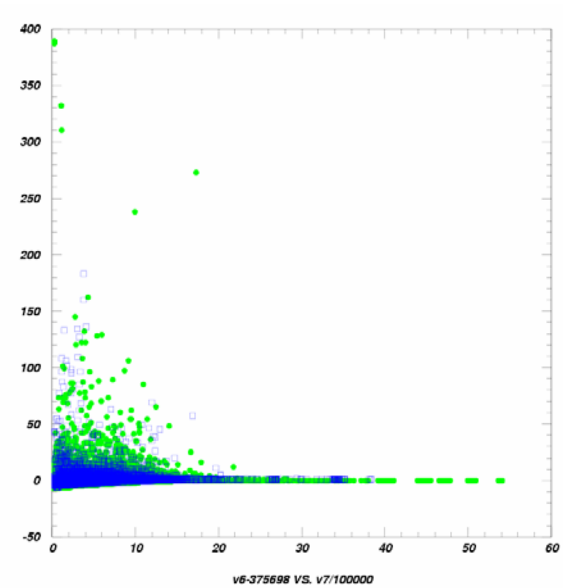
The incident iron nucleus (a charged hadron) enters the atmosphere and appears as a single charged hadron with all (32 TeV) of the energy. After it interacts at ~150 g/cm2, less energy is seen in the charged particles and more gets taken up by photons, neutral hadrons, and leptons.

In the next two plots, Cerenkov photon data is plotted : (top) the production height in cm - the first interaction was forced to occur at ~40 km above the earth, and (bottom) the arrival time at the observation level (~200 m) – offset by the arrival time of the "direct" Cerenkov photons. The Cerenkov photons radiated prior to the first interaction are highlighted inside the total distribution at t = 0 ns. These photons are delayed from the air shower photons by ~8 ns.

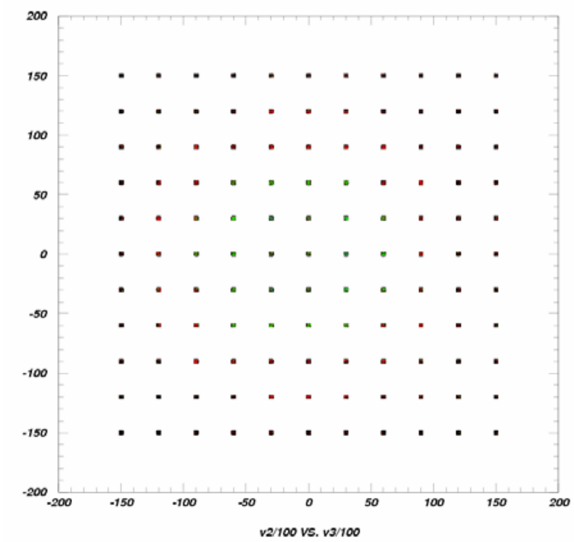




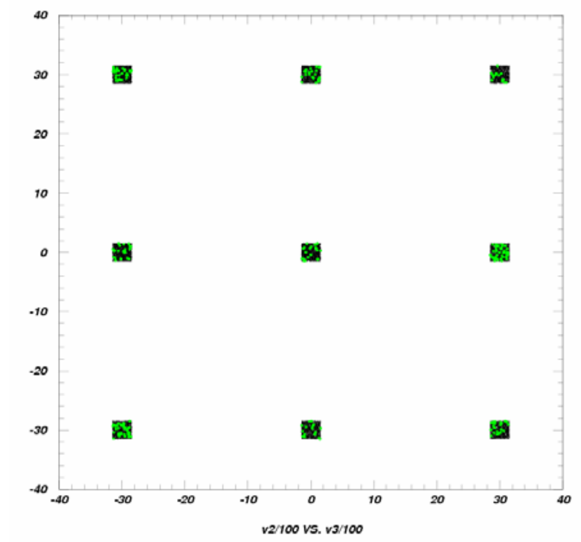
The next plot shows the arrival time in ns of the Cerenkov photons vs their production height in km. Green dots represent all Cerenkov photons and blue squares are those wearing sweaters (I don't remember what the blue is now?).



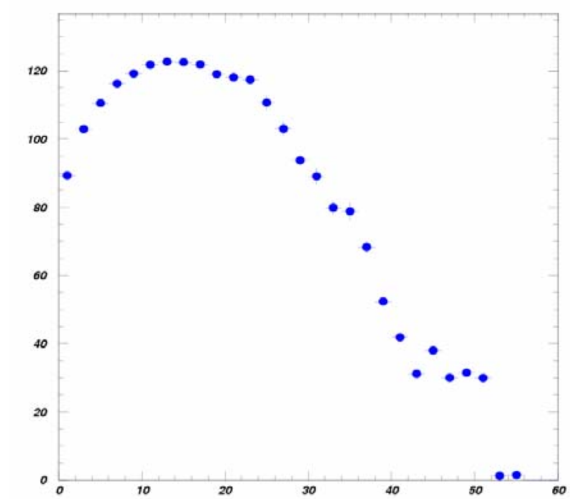
The next plot shows a pattern of telescope "sites" (axes in meters) – with the photon population of each site shown as colored dots. This pattern is determined by the keyword "CERARY" in the input file.



Black dots represent all generated Cerenkov photons in the site. Green dots represent the direct Cerenkov photons produced prior to the air shower. They populate an area of ~50 m x ~50 m compared to the full extent of the air shower which covers the whole plane. Examining the central 3 x 3 array, one can see more closely the relative populations of all photons and those from direct radiation (green). The green dot size has been increased to make it stand out more.



The next plot shows the size in radius (m) of the Cerenkov photons on the ground vs production height in km.

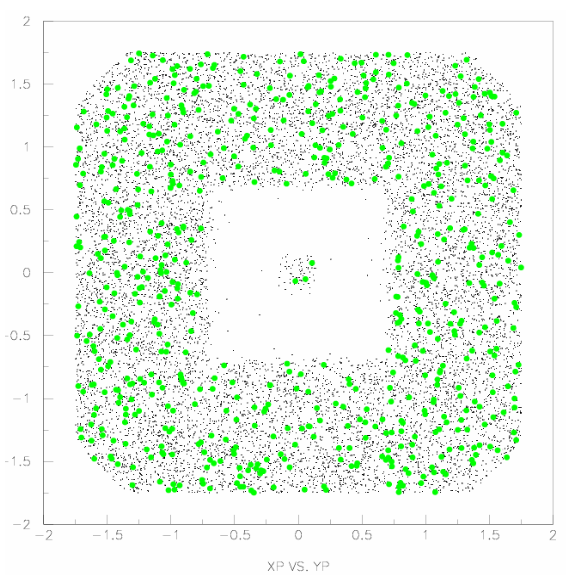


Again, the direct photons (> 40 km) extend out to about 40 m, while the entire air shower photons extend out to beyond 120 m.

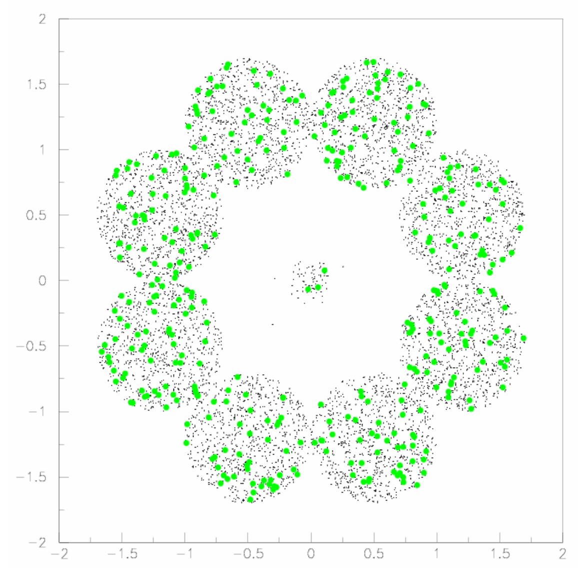
TELE3 ray-tracing program for TRICE Telescope

Cerenkov photons generated by CORSIKA were sent to a program that simulates the TRICE telescope. All photons are tracked through the lens and/or mirror system and tagged according to their final position – of course, we are interested mainly in the photons that propagate to the phototube array, either through the Fresnel lens or through the mirror system.

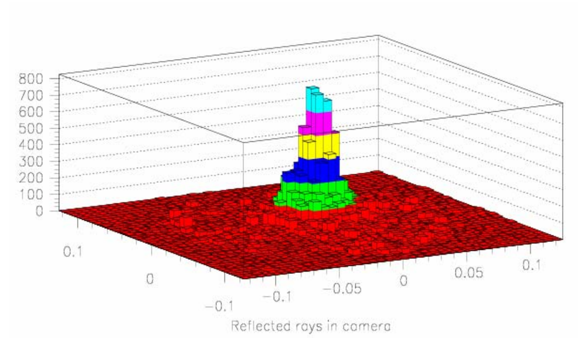
The next plot shows the TRICE site of ~4 m x ~4 m populated by Cerenkov photons. Black dots represent all photons and green dots (enlarged) represent direct Cerenkov photons. The flat mirror plate lets no photons through except through the lens hole as shown.

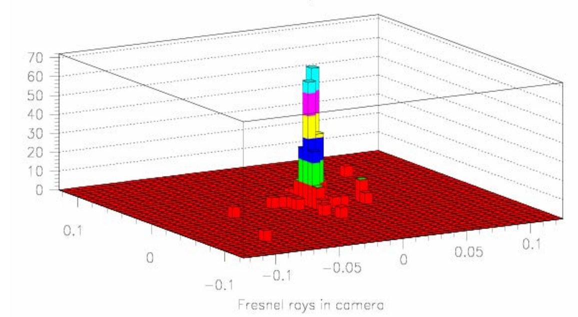


The next plot shows the same distributions of photons, but now only those that reach the phototube array. One can clearly see the outline of the mirrors and lens hole.



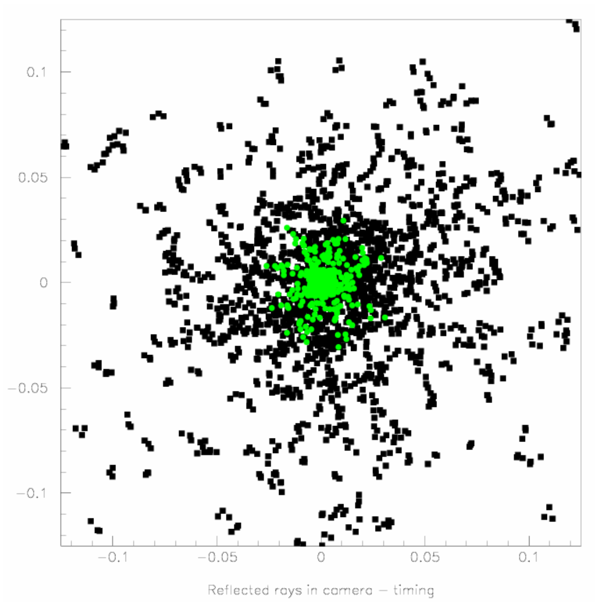
The next 2 plots show the Cerenkov photons in the phototube array (1600 pixels in a 25 cm x 25 cm square array.





The top plot shows the reflected rays through the mirror system (z axis is number of photons) per pixel and the bottom plot shows those through the lens. These photons arrive ~35 ns before the reflected ones.

The final plot shows the 1600 pixels in the phototube array. A timing cut was used to enhance the direct signal. Black are all pixels hit and green are those hit by direct Cerenkov photons as determined by production height.



This is for a shower initiated directly over the TRICE telescope. Presumably, for oblique showers, there would be more separation between the black and green dots.